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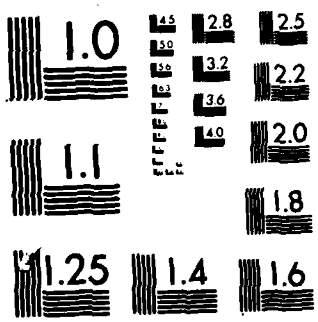

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HILAT: A PRE-LAUNCH OVERVIEW

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13 June 1983

Technical Report

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Plasmapause	Ionospheric F Layer

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Among the many nuclear-weapons effects that must be accounted for in the design of C^3I systems is that of radiowave scintillation produced by scattering in high-altitude structured plasmas. Accordingly, the Defense Nuclear Agency (DNA) conducts a vigorous research program on the nature of such structure and the mechanisms for its production. Past results have indicated significant similarity between that nature and those mechanisms in nuclear-disturbed cases and in the case of the ambient ionosphere disturbed by geophysical processes, the variety of which is

20. ABSTRACT (Continued)

greatest at high latitudes. To further DoD's knowledge of the three-dimensional spectrum of the scattering structures and its understanding of their production, evolution, and decay, DNA and the Air Force Geophysics Laboratory, along with their respective contractors, have joined together to prepare a multi-experiment satellite mission, called HiLat, to collect definitive data on those processes. In view of applications to any military or civilian system that must transmit radio signals through the disturbed high-latitude ionosphere, including for instance satellite-based search-and-rescue systems, cooperation also is being received from the National Research Council of Canada. The satellite designed to meet these diverse but highly complementary objectives, P83-1, is scheduled for launch from Vandenberg Air Force Base at 1530 Z on 27 June 1983. It will carry five experiment payloads, which will (1) directly record radiowave scintillations and employ them for diagnosis of plasma structures, (2) perform *in-situ* measurements at 830-km altitude of plasma density and temperature, including their gradients, and of the vector electric and magnetic fields that largely control plasma dynamics, (3) detect and measure the number and energy flux of precipitating electrons responsible for much of the high-latitude plasma and its structure at the largest scales, and (4) provide a plan-view image of vacuum ultraviolet auroral and airglow emissions from the high-latitude ionosphere on both the day and night sides of the earth. A network of three fixed and two readily transportable receiving stations is being prepared for data collection at geomagnetic latitudes ranging from the plasmapause to the pole, and correlative data are expected from numerous optical and radar remote sensors of the high-latitude ionosphere, including incoherent-scatter radars at polar-cusp, auroral, and possibly plasmapause locations. A Science Team consisting of the DNA Program Manager, the HiLat Project Scientist and Principal Investigators, their collaborating co-investigators, plasma theorists and numericists from the Naval Research Laboratory, and systems specialists from the private sector has been set up to process, analyze, interpret, extrapolate, and apply the experimental results. These resources hold considerable promise for the meeting of HiLat's combined scientific and applied goals, both military and civilian.

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I. INTRODUCTION

In this age of nuclear deterrance, a cornerstone of US national-defense policy is to maintain a credible capability to retaliate against any first strike by an adversary. To provide and to maintain such a capability requires understanding of and design against a miriad of nuclear-weapons effects. To develop such understanding and to provide guidance for such design is a major mission of the Defense Nuclear Agency (DNA).

A key to maintaining a credible retaliatory force lies in C^3 systems that not only could survive a first strike but that also could function in its aftermath. Among the many classes of problems that might have to be dealt with by C^3 systems in that situation are those resulting from radiowave scintillation caused by narrow-angle forward scattering in structured plasmas remaining from high-altitude nuclear detonations. Thus, the transport and structural development of high-altitude plasmas are major research topics of DNA's Atmospheric Effects Division and its contractors.

In the recent past, the DNA research community has learned much about the behavior of high-altitude plasmas through active experiments involving chemical releases and through observation of natural processes in the ionosphere. The latter has been particularly successful in the equatorial F layer, where dominant processes are largely of rather local origin. While many important specifics of the processes by which plasma structures develop, evolve, and decay still are unknown, a good deal of fundamental understanding has been achieved.

The state of understanding of related processes at high latitudes is far less advanced and quite probably of more pressing strategic interest. At geomagnetic latitudes from the plasmapause to the pole, the development of plasma structures that can disrupt radiowave propagation by means of scattering appears to be rather more complicated than at equatorial and middle latitudes. In large part, the complications stem from coupling between the ionosphere and the magnetosphere and, in the case of natural phenomena, between the magnetosphere and the solar wind.

While the writer would not argue that a full understanding of coupling mechanisms, especially at the magnetosphere/solar-wind interface, is necessary for meeting DNA's mission-oriented goals, certain of the high-latitude complications must be confronted to achieve those objectives. Two recent accomplishments suggest that the time is right to do so. First is the fundamental understanding achieved in DNA's equatorial and barium-release programs, which clearly demonstrate the central

importance of various convective instabilities in producing the irregularities responsible for radio-system disruptions collectively described as complex-signal scintillation.

The second contributing accomplishment comprises advances in the understanding of scintillation as a phenomenon, in terms of both signal-statistical description and propagation theory. Central to this second accomplishment of the DNA community was its Wideband Satellite Experiment (Fremouw *et al*, 1978), in which several phase-coherent radio signals spanning a large spectral band were transmitted from a satellite, recorded at carefully selected ground stations, and analyzed in considerable detail. In addition to elucidating the scintillation phenomenon, Wideband also provided descriptive information about the irregularities that cause it, including important information on the three-dimensional configuration of (in addition to the strength of) such irregularities at an auroral latitude.

Wideband was limited in three ways, two of them most limiting at high latitudes. First and foremost, it was strictly a radio-propagation mission, carrying a single experiment payload, the DNA-002 radio beacon. Second, its satellite (P76-5) was locked into a sunsynchronous orbit near the noon-midnight plane. Finally, its global nature precluded detailed probing of the several phenomenologically inter-related but characteristically distinct latitude belts that together make up the high-latitude ionosphere.

A radio-propagation experiment by itself cannot reveal all aspects of the development of scintillation-producing plasma structure. Indeed, it can detect such structure only after it has developed to the point of scintillation production. Other diagnostic instruments are needed to describe the plasma background and sources of free energy that produce the radiowave-scattering structure. That background being most complicated and those energy sources being most numerous at high latitudes, a multi-experiment satellite mission directed at those latitudes is likely to provide numerous insights into plasma structuring at scales that produce deleterious scintillation. The stage has been set for gaining these insights by the understanding of basic processes gained at the less complicated equatorial and middle latitudes.

To meet the aforestated needs and aims and to capitalize on recent research results, DNA has planned and prepared a multi-experiment satellite mission — called HiLat -- for describing and understanding high-latitude plasma structures. Stemming from a suggestion by the author (Fremouw, 1980, 1981) and from several other sources, and guided by DNA's Atmospheric Effects Division, preparations for the HiLat mission have gone smoothly through the date of this writing, just two weeks before launch.

Launch of the satellite (P83-1) is planned from Vandenberg Air Force Base (VAFB) on 27 June 1983 by means of a four-stage Scout vehicle.

Several organizations have contributed vigorously to preparations. Expeditious preparation of the spacecraft, a modified operational-class Transit, has been performed by the Applied Physics Laboratory (APL) of Johns Hopkins University, under the direction of Dr. Kenneth Potocki, HiLat Project Engineer. The launch vehicle has been prepared by Vought Corporation under supervision of NASA, and launch preparations are being coordinated by USAF Space Division. A multi-organization Mission Working Group was formed and has persistently proceeded toward launch.

Meanwhile, a strong Science Team has been formed under the leadership fo DNA's Program Manager, Major Leon Wittwer, and the author, who is acting as HiLat Project Scientist under a contract from DNA to Physical Dynamics, Inc.'s Northwest Division (PDNW). This document constitutes the final report on preparation activities carried out under that contract.

Deterrance requires not only operability of systems in the aftermath of an adversary's strike but also, *a fortiori*, operation under any and all naturally occurring conditions. As DNA is chartered to understand and describe nuclear-weapons effects, so the Air Force Geophysics Laboratory (AFGL) is chartered to understand and describe geophysical phenomena and their effects on military systems and to provide guidance for design and operation of those systems under all geophysical conditions.

Past research by DNA and AFGL clearly has demonstrated close physical ties between scintillation-producing plasma structure that would follow a high-altitude nuclear detonation and such structures produced in the ambient F layer under naturally disturbed geophysical conditions. Moreover, nuclear-produced scintillation effects on C^3 and surveillance systems probably would differ mostly only in degree from their naturally produced counterparts, differing little in their qualitative nature. Thus, HiLat can serve mission-oriented goals of AFGL as well as — indeed, even more directly than -- those of DNA. Accordingly, extensive cooperation on the program is being received from AFGL and its contractors, with Principal Investigators (P.I.'s) on three of HiLat's five experiments being AFGL staff members. The other two P.I.'s are from APL and SRI International, with experiment payloads being built there and at AFGL, with assistance from the latter's contractors, the University of Texas at Dallas (UTD) and Regis College.

So long as deterrance succeeds, there will be other operational applications of the research results expected from HiLat. Among them are remote sensing and communications for scientific, commercial, and other civil purposes that require

transionospheric radiowave propagation at high latitudes, including application to satellite-based search-and-rescue systems. For these and possibly other of its own sovereign purposes, Canada has joined with the US in preparations to field HiLat. Specifically, the National Research Council of Canada (NRCC) has cooperated in preparation of a formal agreement between the Canadian and US governments for collection and sharing of data from HiLat.

The University of Western Ontario (UWO) is developing a transportable receiving system for collection of HiLat data at a number of locations by a consortium of Canadian universities. Other data-collection receivers are being constructed by SRI and PDNW for observations at a network of other northern-hemisphere stations at latitudes ranging from the plasmapause to the polar cusp. A three-year initial observing period, starting in the second half of 1983, is envisioned.

II. OBJECTIVES

The ultimate objective of HiLat is to provide a sound scientific basis for designing C^3I systems and procedures that will effectively be immune from disruption by radiowave scintillation. The signal-statistical and propagation-theoretical tools for doing so already exist in computer codes designed for describing such effects of both the ambient and nuclear-disturbed ionosphere. What remains is a reliable description of scintillation-producing irregularities in plasma density under relevant conditions, including the transport and morphological evolution of those irregularities.

For application to understanding and predicting of high-altitude nuclear effects (HANE), the objectives of HiLat are double-edged. The first edge may be characterized as *using the high-latitude ionosphere* as a laboratory for understanding the processes of development, evolution, and decay of structured plasma enhancements at any latitude, including middle ones.

The high-latitude F layer, in both its auroral and polar regimes, is replete with naturally occurring arcs, blobs, patches, and other forms of plasma enhancement, presumably due ultimately to precipitation of energetic particles from the magnetosphere. Moreover, the cross-polar-cap electric field provides a ready source of free energy for convectively transporting such features, apparently through large distances, during which scintillation-producing irregularities may develop due to convective instability. The attendant dynamics are sufficiently closely related to those that would act on high-altitude nuclear plasmas that properly interpreted observations of the former should provide insight into the evolutionary development and decay of the latter.

The second HANE objective -- *the back edge of the first*, as it were -- has to do specifically with the high-latitude environment itself. The HiLat mission affords a context in which to formulate and probe pertinent questions that have not been asked in an ordered way before, questions such as "What would be th geophysical consequences of large-scale nuclear engagement at high latitudes?"

One set of such questions arises at the equatorward limit of HiLat's intended observing window, the plasmapause. In terms of natural processes, one might suppose HiLat's window of interest to end at the equatorward boundary of soft electron precipitation or, at least, no farther equatorward than the "bottom" of the main ionospheric trough (Muldrew, 1965). Strategically, however, such a cutoff of HiLat coverage would make no sense. The next step equatorward in geomagnetic latitude

cuts a swath across the heavily inhabited and industrialized northern tier of CONUS and a similar swath across the northern third of the USSR. In this next latitude belt lie the ionospheric projection of the plasmapause (Rycroft and Thomas, 1970) and the only scintillation-producing irregularities of consequential strength (for most radio-wave systems) known to exist in the ambient, mid-latitude ionosphere.

Under highly disturbed nighttime conditions, observations of the Wideband satellite showed a region of severe scintillation (averaging about three radians of rms phase fluctuation at VHF with a 10-sec detrend period) centered in the F layer at about 56° geomagnetic invariant latitude (Fremouw and Lansinger, 1981a). Houminer *et al* (1981), using a geostationary-satellite link with an F-layer penetration point at 53.3° invariant latitude, found strong amplitude scintillation in the nighttime hours during magnetic storms. Based on non-simultaneous measurements of total electron content (TEC) along a radio path through essentially the same region, they attributed these scintillations to irregularities formed on the equatorward wall of the trough -- i.e., at the plasmapause.

An earlier study by Basu (1974), also using geostationary satellites, disclosed a storm-time dependence of enhanced nighttime scintillations near the trough wall and associated them with the heat flux thought to cause stable auroral red (SAR) arcs (Cole, 1965). Theoretical work by Hudson and Kelley (1976) offers a likely candidate for an irregularity generation mechanism energized by this heat flux, the thermal-density-gradient (TGD) instability. Comparison with the work of Keskinen and Ossakow (1982) shows the TGD instability to be a member of the family of convective interchange instabilities known to cause structuring of high-altitude plasmas.

The thermal flux referred to above is thought to be in the nature of an electron heat flow, the energy for which comes ultimately from ring-current protons. The plasma trapped in the radiation belts after a HANE event presumably stores significant amounts of energy that could be released into the ionosphere from the enhanced ring current. At very late times after such an event, one might expect conditions qualitatively like natural ones but quantitatively more energetic. At northern CONUS and USSR latitudes, one might then find enhancement of processes normally occurring there, such as SAR arcs and, possibly, TGD instability and resultant scintillation. Assessment of the potential for enhancement or alteration of such naturally occurring geophysical processes is an example of the "reverse edge" of HiLat objectives.

Returning to the "natural-laboratory" aspect of those objectives, there are several hypotheses to be explored. We shall not list here all of these hypotheses and

evolving concepts, since they have been documented by Vickrey (1982) and distributed by Fremouw and Secan (1982). We point out, however, that they fall into two broad categories, which themselves may be viewed as competing hypotheses.

On the one hand is the view that the dominant source mechanism for scintillation-producing irregularities is convective instability, which proceeds independently of latitude, origin of the plasma, and other circumstances. The oppositely extreme view would be that the plasma source plays a dominant role in dictating the shape and strength of the irregularities (and, therefore, the specifics of scattering geometry and severity). In the ambient high-latitude ionosphere, for instance, the latter view would postulate that the spatial spectrum of scintillation-producing irregularities is laid down directly by structured particle precipitation. In the HANE case, debris clumping or some other early-time process would be important in dictating the plasma-structure spectrum at late times.

The foregoing two views may well represent two overly simplified aspects of the actual situation, both in the HANE environment and in the ambient ionosphere. The overriding direct objective of HiLat is to sort out the degree to which (a) early-time structure in the plasma source and (b) subsequent development by convective processes, essentially independently of the source, dictate the three-dimensional spatial spectrum of scintillation-producing irregularities. A corollary objective to (b) is to establish the degree, if any, to which convective drivers (gravity, neutral winds or heave, electrostatic convection augmented by field-aligned currents, thermally driven "plasma winds," or a driver yet to be recognized) affect the irregularity spectrum and its evolution.

The key to meeting the foregoing overriding direct objective is to observe, collate, and understand similarities and differences in the three-dimensional spatial spectrum of scintillation-producing irregularities under disparate, categorized geophysical conditions. In HiLat, the three-dimensional spectrum will be observed with two instruments: a radio-wave beacon and an *in-situ* plasma monitor.

By observing the geometrical dependence of scintillation (Fremouw and Lansinger, 1981b) and more directly by means of spaced-receiver observations (Livingston *et al*, (1982), the beacon can reveal much about the three-dimensional shape of the irregularities. (By the same token, knowledge of the shape permits calculation of the geometrical dependence of system disruption in applications codes.)

For instance, the Wideband beacon disclosed a theretofore unexpected cross-magnetic-field anisotropy of irregularities in the diffuse-auroral region (Fremouw *et al*, 1977; Rino *et al*, 1978). Ascertaining whether or not this anisotropy is unique to a

narrow belt of geomagnetic latitude is important for improvement of operational codes for assessing scintillation effects on communication links through the ambient ionosphere (Secan and Fremouw, 1983). Whether it stems directly from laydown of sheetlike irregularities by latitudinally irregular electron precipitation or results solely from a (possibly locally unique) characteristic of electrostatically driven plasma convection (Livingston *et al*, 1982) is pertinent for assessing the importance of plasma-source characteristics to the enduring shape of scintillation-producing irregularities. Comparison of beacon data with spectral analyses of electron precipitation fluxes observed by means of another of HiLat's instruments (the "J-package") should provide a direct test of the former possibility. Detailed analysis of spaced-receiver data from the beacon, establishing the scale-size dependence, if any, of the observed cross-field anisotropy (Secan and Fremouw, 1983) also should yield insights into a possibly complicated interplay between plasma laydown and subsequent convective restructuring.

The general character of the irregularity spectrum may be deduced from spectral analysis of phase scintillations. Comparison of those results between different high-latitude regimes and between the high-latitude and equatorial (Livingston *et al*, 1981) regions should reveal the dependence or independence of the spectrum on different convective drivers. Certain specific aspects of the irregularity spectrum, however, are difficult to obtain from the phase spectrum. For instance, the outer scale, which is a parameter employed in certain important applications codes, is difficult to ascertain from scintillation data because of the path-integral nature of the measurement and the changing geometry as the ray-path to an orbiting satellite scans. Features such as an outer scale may be discernible in data from the *in-situ* plasma monitor.

Other relevant scale sizes, such as a preferred "minimum" striation size, may be identifiable in both properly analyzed (windowed) phase and *in-situ* data. The relationship of such characteristic scale sizes to physical conditions in the background plasma, such as F-layer and E-layer conductivity, the conditions needed for anomalous diffusion by drift waves, and the existence and influence of E-layer "images" of F-layer structures constitutes another relevant direct objective of HiLat.

By no means does the foregoing discussion exhaust the list of HiLat's specific observational and data-analytical objectives; rather, it is a representative sampling. Taken together, the specific objectives may be stated to be (1) to extend our data base on the strength and three-dimensional shape of scintillation-producing irregularities for use in operational codes addressing systems effects of the ambient ionosphere, (2)

to document the degree of dominance of plasma convection in the development of scintillation-producing irregularities and the consistency or lack thereof in the three-dimensional spectrum of such irregularities produced by different convective drivers under different conditions, (3) to identify the degree to which initial structures in the source plasma dictate the character of enduring structures at scintillation-producing scales, and (4) to seek out other irregularity source mechanisms (e.g., imposed electrostatic turbulence).

In short, the objectives of HiLat are to identify and understand irregularity source mechanisms, transport behaviors, redistribution patterns, spectral evolution, scale-size-dependent lifetimes, and decay mechanisms from the plasmapause to the pole.

III. THE HILAT EXPERIMENTS

To meet the objectives outlined in Section II, a unique combination of five experiment packages has been assembled in the HiLat Satellite. By means of these payloads, it will be possible to (1) observe complex-signal scintillations at VHF and UHF and infer ionospheric TEC from measurement of radio-frequency dispersion; (2) measure *in-situ* plasma density and temperature, electric and magnetic fields, and both precipitating and upwelling electrons; and (3) make plan-view extrapolations by means of vacuum-ultraviolet (VUV) images of both nightside and dayside auroras and, probably, F-layer plasma-density enhancements.

The main features of the instruments are summarized in Table 1, along with their P.I.'s and collaborating investigators from participating organizations.* The following instrument sketches have been assembled from information provided by the P.I.'s.

A. Beacon

The HiLat multi-frequency coherent radio beacon is a modified (less ambitious) version of the ten-frequency DNA Wideband beacon carried on Satellite P76-5 (Fremouw *et al*, 1978). It has, in fact been prepared by modifying the spare payload from the Wideband mission. It will transmit coherently on five frequencies: one at VHF (137.676 MHz), three at UHF (390.082, 413.028, and 435.974 MHz), and one at L Band (1239.084 MHz). As in Wideband, complex-signal scintillation measurements will be made at VHF and UHF, and the triplet of UHF cw signals will be used to obtain TEC from measurement of the second difference of phase, $\Delta_2\phi$ (Burns and Fremouw, 1970). The L-band signal will serve as a phase reference for the VHF and UHF scintillation measurements, and it will be available for observations of amplitude scintillation at L band (as was the S-band reference in Wideband).

The L-band and VHF transmissions will be with right-hand circular polarization, but the UHF signals will be transmitted with left-hand circular polarization. The difference is to minimize interaction between the UHF and L-band antennas, which are nested volutes mounted on the nadir-facing surface of the three-axis-stabilized spacecraft. The VHF antenna is a tripole mounted on the end of one of the solar panels.

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*In addition to the experimenters identified in Table 1 and their associates at the indicated organizations, the HiLat Science Team includes Drs. Keskinen and Ossakow of the Naval Research Laboratory (NRL), Kilb of Mission Research Corporation (MRC), Vickrey of SRI, and Wittwer of DNA.

Table 1. THE EXPERIMENTS

PAYLOAD	OBSERVABLES	CHARACTERISTICS	EXPERIMENTERS
BEACON	Scintillation TEC	138, 390, 413, 436 MHz 1239-MHz reference Circular polarization	Carlson et al (AFGL) Forsyth et al (UWO) Fremouw et al (PDNW) *Rino et al (SRI)
PLASMA MONITOR	(Log N_e), N_e, T_e N_i, N_{O+}, N_{H+}, T_{H+} $\vec{V}_d \Rightarrow \vec{E}$	Langmuir Probe RPA Ion Drift Meter	Hanson (UTD) Heelis (UTD) *Rich (AFGL)
ELECTRON SPECTROMETER	Electron FLux & Energies	20 ev - 20 kev Zenith, Nadir, 40°	*Hardy (AFGL)
MAGNETOMETER	$\vec{B}$, $\Delta\vec{B} \Rightarrow \vec{J}$	3-axis fluxgate	*Potemra (APL)
AIM (VUV IMAGER)	Auroral & Airglow Images & Spectra	1150 - 2000 Å Also 3914 & 6300 Å (Fixed Photometers)	*Huffman (AFGL) Meng (APL)

*P.I.

The effective radiated power (ERP) near the center of the antenna beams will be 26 dBm at VHF, 21 dBm for each of the three UHF signals, and 30 dBm at L band. Given the satellite's intended 830-km circular orbit, the VHF power received by an isotropic antenna will range from -119 dBm at 15 elevation to -108 dBm overhead, UHF power from -130 dBm to -123 dBm (on each spectral line) at the same elevations, and L-band power from -128 to -123 dBm.

Unlike the Wideband phase reference, the L-band signal from HiLat will not be a clean cw carrier. Because the P83-1 spacecraft has no onboard recording capability, HiLat data will be transmitted to beacon and telemetry receiving stations in real time. The L-band beacon channel will carry the telemetered information, at 4098 bps, from the *in-situ* and imaging experiments. A split-phase modulation waveform will be used to produce a BPSK signal in the L-band channel. The carrier suppressed in this signal will be reconstituted in resynchronization loops at the ground stations.

B. Plasma Monitor

The main payload for *in-situ* measurements consists of three sensors: a Langmuir probe, a retarding-potential analyzer (RPA), and an ion drift meter, mostly of proven design (Smiddy *et al*, 1978). This combination of sensors, collectively referred to as the plasma monitor, will provide information on electron and ion density and temperature and on ion mass and drift velocity, the latter for purposes of deducing the *in-situ* electric field. It will operate on a 64-sec data cycle.

The electron sensor is a spherical Langmuir probe, constructed to exclude thermal ions (energy < 20 ev) and to measure the collected electron content. For 62 out of each 64 seconds, a small positive voltage will be applied to the probe's spheres, and the collected direct current will be output 32 times per sec. This current will provide an approximate measure of absolute electron density and an accurate measure of spatial variations in density as the satellite moves through the topside F layer.

In addition to being directly sampled 32 times per sec (spatial resolution of 232 m), the electron-current fluctuations will be used to provide a statistical measure of small-scale irregularity strength. Specifically, the current will be passed through a logarithmic amplifier and a bank of bandpass filters with center frequencies of 70, 220, 700, and 2200 Hz, the outputs of which will be detected and then sampled once per sec. The samples will correspond to measurements of spectral density of the quantity $\Delta\log(N_e) \approx \Delta N_e/N_e$, where N_e is electron number density, at spatial wavelengths of 106, 34, 11, and 3 m, respectively, with a sample resolution of 7.4 km.

For two seconds out of each 64, a sequence of voltages will be applied to the probe spheres. Analysis of the current-vs-voltage (I-V) curve will yield a measurement of the vehicle potential, the absolute electron density, and the electron temperature, with a spatial granularity of 476 km (3.8° of orbital arc). (During these periods, the filter-bank outputs will not be meaningful.)

The RPA is a Faraday cup with a circular aperture through which ions must pass before reaching the collecting plate. Thermal electrons (energy < 20 ev) will be repelled from the collector. Unlike the Langmuire probe, whose voltage will be fixed most of the time in the HiLat mission, the RPA's collector voltage will be swept most of the time. Analysis of the I-V curve for the resulting ion current will produce measurements of total ion density (within about ±25%), specific densities of 0+ and H+, and the temperature of H+. In addition, from knowledge of vehicle attitude and velocity, the measured energy of the incident thermal ions will be used to obtain the component of plasma drift parallel to the vehicle velocity (i.e., in the "ram" direction).

The ion current from the RPA will be sampled periodically 32 times per sec, but the sweep rate of the applied voltage will be varied through the 64-sec data period. Most of the time, during seconds five through 32 and seconds 37 through 62, the set of measurements will be obtained with a resolution of 5.0 km by means of two sweeps every three seconds. Slower sweeps, one per three seconds, will be carried out during seconds one through three and 33 through 35, with one additional sweep each being made in seconds four and 36. There will be no RPA measurement during seconds 63 and 64.

The drift meter is a Faraday cup with a square aperture facing in the ram direction and a collecting plate split into four quadrants. Again, ions will flow through the aperture to the collector, with electrons being repelled. The ratios of currents flowing from the four collector sectors due to the partially occulted beam of thermal ions is a measure of the angle of plasma flow relative to the satellite velocity vector, given accurate spacecraft attitude information. Current-ratio measurements will be made 32 times per second, with the quadrant pair alternated to give measurements of the horizontal and vertical components of cross-track velocity (V_y and V_z, respectively), within about 30 m/s, each at a rate of 16 per second to yield a vector resolution of 465 m. The ram-direction velocity component, V_x, will be obtained to within about 200 m/s, with a resolution of 5.0 m from the RPA, as described above.

C. Electron Spectrometer (J-package)

As a means for identifying a primary, spatially irregular source of ionization, HiLat will carry an electron energy spectrometer. It will measure the number and

energy flux of electrons in each of 16 channels in the energy range between 20 ev and 20 kev, using instrumentation developed for DMSP. This so-called J-sensor will contain three detector assemblies, one directed at the local zenith and therefore close to the magnetic field lines at high latitudes, one directed at the nadir and therefore sensitive to upwelling energetic electrons, and one looking 40° from the zenith.

Each detector assembly will include two cylindrical electrostatic analyzers, one covering the range from 20 ev to approximately 600 ev in eight channels and the other covering the range from 600 ev to 20 kev in another eight channels. Apertures limit the acceptance beam to 4° x 6° for the low-energy channels and to 2° x 9° for the high-energy ones. The fractional energy-spectral channel widths, $\Delta E/E$, are 0.13 and 0.09 for the low- and high-energy detectors, respectively.

The J-sensor will be operated in three different modes, as program-selected from a ground station. The routine-monitor mode will employ all three detectors and all energy channels, each combination being sampled four times per second and thereby yielding a spatial resolution of 1.9 km. In the single-sensor, full-spectrum mode, each energy channel of the zenith-directed detector, only, will be sampled 12 times per second, giving a resolution of 620 m. Finally, in the high-resolution mode, each of the eight low-energy channels (20 to 600 ev) from the zenith-directed detector, only, will be sampled 24 times per second. In this mode, low-energy precipitating electron flux will be recorded with an in-orbit resolution of 310 m. Thus, the HiLat J-sensor will be quite capable of detecting direct laydown of F-layer plasma by electron precipitation that is spatially irregular on scintillation-producing scales.

D. Magnetometer

The velocity measurements made by means of the ion drift meter and the RPA will be used to deduce the local convective electric field, partly for investigating the role of the $\vec{E} \times \vec{B}$ instability in the development of scintillation-producing irregularities. To assess the contribution made by the current-convective instability to $\vec{E} \times \vec{B}$ stable regions and to investigate other aspects of field-aligned and horizontal currents, HiLat will carry a three-axis fluxgate magnetometer of proven design.

The local vector magnetic field will be measured, within about 12 nT, twenty times per second, yielding a resolution of 372 meters. By comparison with a magnetic-field model, the magnetometer outputs also will contribute to determination of spacecraft attitude, which is needed for interpretation of data from several of the instruments.

E. Auroral Ionospheric Mapper (AIM)

The foregoing experiments are intended to identify and describe scintillation-producing irregularities and to measure geophysical quantities relevant to their production and evolution. The final instrument, which also is the most novel, is intended to give simultaneous synoptic information through optical remote sensing of the ionosphere. The instrument consists primarily of a vacuum-ultraviolet (VUV) imaging spectrophotometer, augmented with two visible-wavelength fixed photometers.

The VUV instrument consists basically of an ultraviolet detector sensitive between 1150 and 2000 Å, a means for selecting wavelength with a bandwidth of 30 Å, and a cross-track scanning mirror for the purpose of producing images as the satellite moves above the auroral and ionospheric-airglow emitting regions. The instantaneous optical field of view is $0.37^\circ \times 1.53^\circ$, yielding a nadir resolution of 3 by 13 km in the F layer (350 km altitude) and 5 by 20 km in the E layer (110 km). The detector has a design dynamic range of 10 to 10^5 Rayleighs and a demonstrated sensitivity of 27 Rayleighs at 1300 Å.

The AIM concept is based on measurements made on S3-2 with a fixed VUV spectrophotometer (Huffman *et al*, 1980), which demonstrated the measurability of several VUV spectral lines in the aurora and airglow. Of particular potential interest for F-layer studies is a radiative recombination line of O I at 1356 Å (Chandra and Reed, 1975).

The AIM instrument is capable of operating in three different modes. In the simplest, the wavelength would be set at any one of nine selectable values and the mirror locked in its nadir position. This fixed-photometer mode is not planned in normal operation, but will be available for special studies or in the event of instrument problems. For spectral studies, the instrument will be run in spectrometer mode, in which the mirror will be locked at nadir but the wavelength will be continuously scanned across the entire spectrum from 1150 to 2000 Å once each three seconds.

The most ambitious of the three modes, and the one that probably will be used most of the time, will provide a plan-view image at any of nine selectable wavelengths. A cross-track line scan of 134.4° by 1.5° will produce 336 pixels every three seconds, the centers of the 13-km-wide F-layer (20-km-wide E-layer) scans being about 22 km apart.

The two fixed visible-wavelength photometers will operate at 3914 and 6300 Å.

IV. THE P83-1 SATELLITE AND ITS ORBIT

A. The Satellite

The P83-1 spacecraft is a modified OSCAR-class ('O' for Operational) TRANSIT satellite from which the navigation electronics have been removed to make room for scientific payloads. Following the approach used in P76-5 (Wideband), the OSCAR has been augmented with an additional payload-housing structure or "penthouse." In addition to the Wideband-like penthouse, HiLat contains an experiment base, on which are mounted the AIM and the UHF/L-band beacon antennas.

The OSCAR body is octagonal, with the penthouse and experiment deck mounted on its nadirward end. The main assembly is approximately four feet long, including the UHF beacon antenna, and approximately two feet in diameter. Appendages include four 66-inch-long solar panels, on which are mounted two of the three magnetometer sensors, the VHF beacon antenna, and command and spacecraft housekeeping (non-science) telemetry antennas. The entire satellite weighs 225 pounds and makes use of approximately 45 watts of solar power.

Three-axis stabilization to within 10° will be provided by a 90-foot gravity-gradient boom extending toward the zenith and a momentum wheel mounted on the side of the penthouse. The attitude will be sensed to within ±2° by means of sun sensors and the magnetometer, and then telemetered to the ground in the science data stream.

A full description of P83-1 is given in the Johns Hopkins University Applied Physics Laboratory report JHU/APL SDO/PAO-0348A, dated February 1983.

B. The Orbit

The HiLat orbit has been optimized for its multi-experiment mission, which represents some compromise between individual experiments. First, it is necessary that the satellite be above the strongest region of scintillation-producing irregularities, which is in the center of the F layer (350 km, say), so that the beacon signals propagate through them. For full-earth coverage by the AIM, one would like an even higher orbit. For *in-situ* ionospheric measurements, however, the sensors must be within the ionospheric plasma.

Taken together, the foregoing altitude requirements argue for an orbit in the topside F layer. Simultaneity of useful measurements from all the experiments is to be a central feature of the HiLat mission, so optimization of altitude for different

experiments at different times by means of an eccentric orbit was not a viable option. Accordingly, a circular orbit at 830 km was chosen.

The matter of inclination, which controls precession rate for a chosen altitude, was given careful consideration. The Wideband satellite has sampled scintillation conditions well in the auroral zone in local-time sectors fixed by its nearly noon-midnight sunsynchronous orbit. One objective of HiLat is to extend the resulting scintillation data base to other portions of the high-latitude region and to other local-time sectors. For this purpose, a decision was made to select a fairly rapidly precessing orbit. It is also desired in HiLat to sample a given location, local time, and observing geometry in different seasons of different years, so seasonal synchronism was to be avoided.

The window of inclinations achievable from VAFB ranges from 77° to 146°. The desires for rapid solar-time precession and high-latitude observations combined to give preference to prograde orbits within that window, that is 77° to 90°. Specifically, to obtain passes over the magnetic pole, an inclination of at least its geographic latitude (80.6°) is needed. Going too high, however, would slow the precession rate.

On the foregoing basis, the inclination was narrowed to between about 80° and 85°. It was noted that the complement of DMSP's inclination falls within this range, and that picking that complement would permit rather direct comparisons between observations from the two spacecraft going in opposite directions during seasons when the two would be coplanar. On this basis, the specific inclination of 82.2° was picked.

Thus, the intended HiLat orbit is circular at 830 km altitude and 82.2° inclination. This results in a period of 101.5 min and a solar-time precession rate of -7.47 min/day. That is, the orbital plane will be over a given station 7 min 28 sec earlier each day, so that observing both ascending and descending passes will permit measurements throughout all local times in 0.26 year, or a little over a calendar season. The orbital velocity is 7.436 Km/s. An overhead pass will take 15.7 min from horizon to horizon, or 11.2 min above 10 elevation.

V. DATA COLLECTION, PROCESSING, AND DISTRIBUTION

A. The Receiving Stations

As of this writing, five HiLat beacon and telemetry receivers are planned. Three of them will be at fixed stations, and two will be readily transportable. Two of the fixed stations (Tromso, Norway and Churchill, Manitoba, Canada) are in the auroral zone, and one (Sondre Stromfjord, Greenland) is near the polar cusp. One of the transportable stations will be headquartered at a plasmapause station near Seattle, WA, and the other will be used at a number of stations in Canada. The Seattle-based system is being developed for use in AFGL's Flying Ionospheric Observatory as well as for ground-based use.

Figure 1 shows the locations of the fixed ground stations and several likely locations for transportable-station campaigns, in offset-magnetic-dipole coordinates. The fixed stations and Seattle are indicated by stars, as are Boston, MA, Barrow, AK, and Inuvik and Cambridge Bay, NWT (four likely locations for transportable-station campaigns). Shown as a circle-dot is Thule, Greenland, near the north geomagnetic pole, at which a beacon-only receiver will be located.

Also shown on the figure are data-coverage circles for the four stations to be operated initially and most of the time, the three fixed stations and Seattle. The solid circles around the stations indicate the locus of line-of-sight penetration points of the F layer (350 km) when the satelite is at 10° elevation, thus depicting approximately the scintillation-producing region observable from each station by means of the beacon. A similar circle around Thule shows beacon coverage from there.

The dashed circles around the four fully instrumented stations are loci of the corresponding subsatellite points, thus representing the regions of *in-situ* coverage from each of those four stations. Imager coverage, of course, will extend well outside these circles and will cover essentially the entire northern high-latitude region of interest when data from the four stations are combined.

Finally, the figure shows two tracks of the satellite, one nearly overhead at Seattle, Cambridge Bay, Thule, and Tromso, and one overhead at Thule and Sondre Stromfjord. Note that the orbit selected produces passes nearly along the geomagnetic meridian at high-latitude stations. When ascending passes do so at a given station, the descending passes cut steeply across the meridian, and vice versa.

Figure 2 shows the main elements of a HiLat receiving station. The beacon's VHF, UHF, and L-band signals will be received at a main antenna array near the

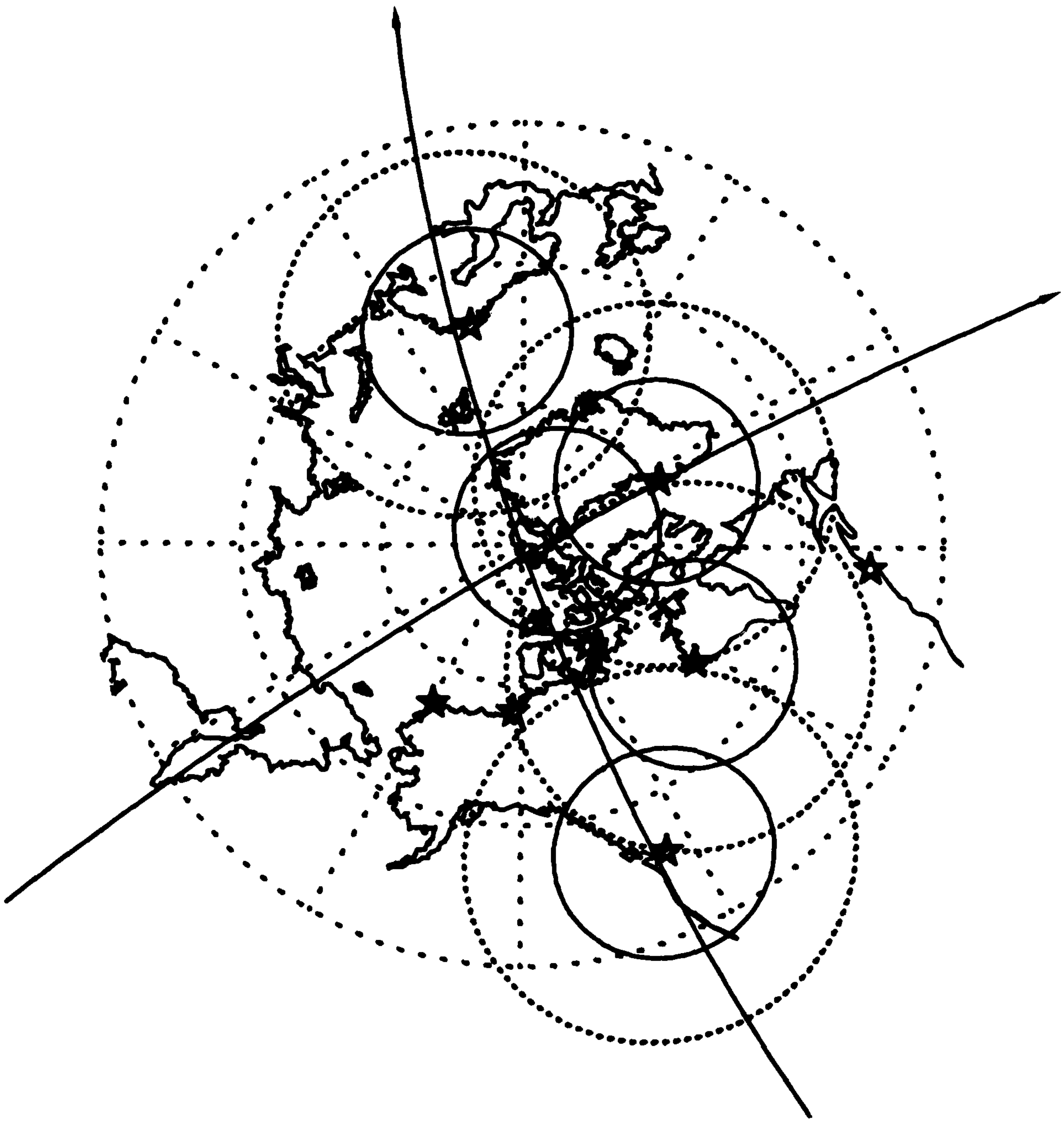

Figure 1. HiLat receiving stations and data coverage in offset-magnetic-dipole coordinates.

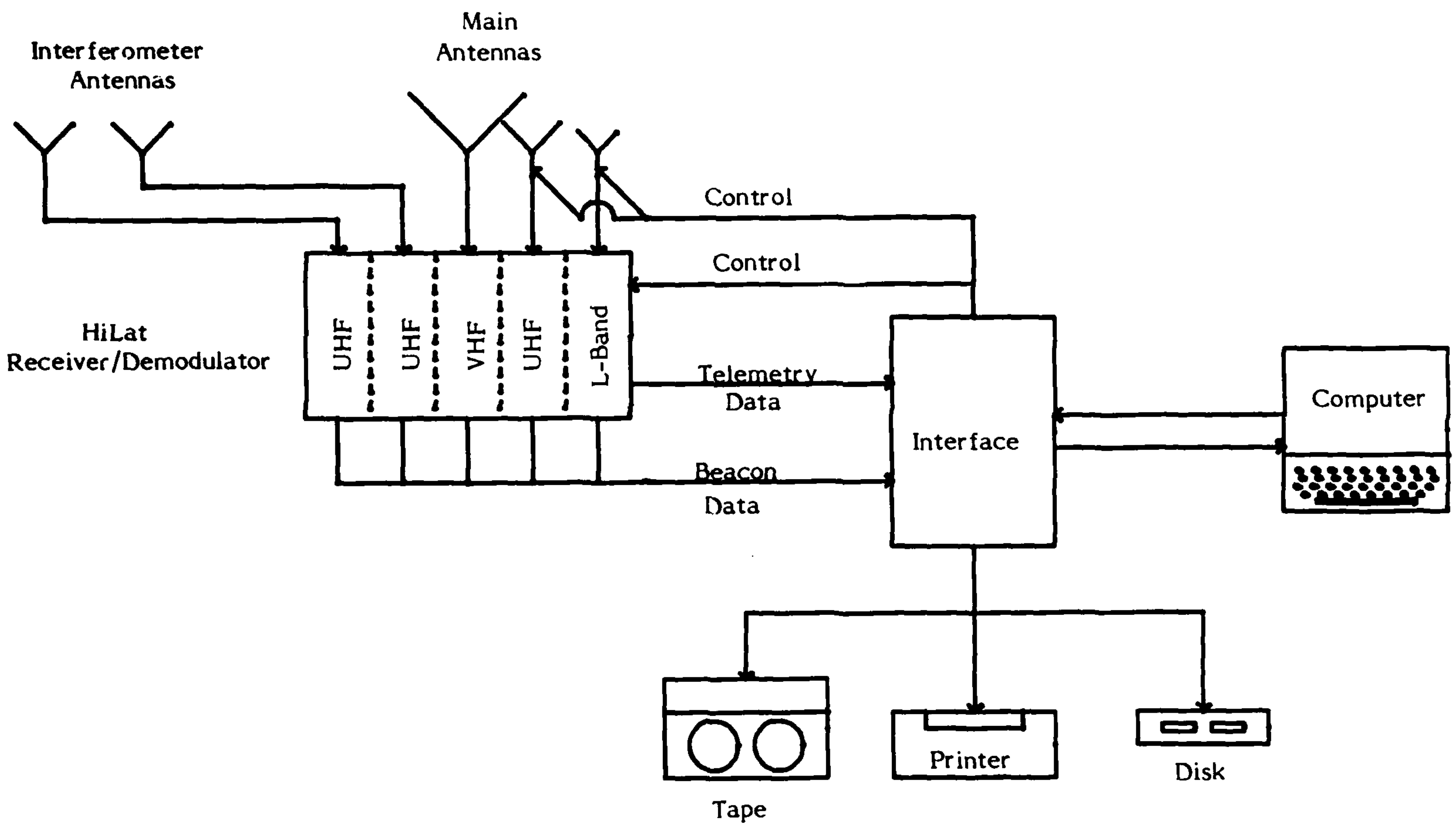

Figure 2. A HiLat receiving station.

receiver building or trailer, and the 413-MHz UHF signal also will be received at two remote antennas, placed several hundred meters away on geomagnetic north-south and east-west baselines.

The HiLat receiver/demodulator has several functions. First, it must receive, amplify, and coherently detect the beacon signals, outputting the baseband in-phase and quadrature (I and Q) components of the scintillating VHF and UHF signals, employing a phase reference derived from the L-band signal. To obtain the phase reference, the receiver's L-band section contains a resynchronizing loop for reconstituting the L-band carrier suppressed by the BPSK data modulation. The phase of the reconstituted carrier will be used to lock the entire receiver to the beacon's basic oscillator, with the frequency-differential effects of geometrical doppler automatically removed. The amplitude of the reconstituted carrier will be recorded as a measure of L-band scintillation. Finally, the system will demodulate the BPSK L-band signal and pass the bit stream from all the non-beacon experiments to the station computer.

Three receivers from the Wideband Experiment are being refurbished and modified, by SRI, for use at the fixed HiLat stations. A new, more compact receiver is being developed, by PDNW, for transportable use as well as for airborne operation. Functionally, the two types of receiving stations differ primarily in the nature of their associated computers. At the fixed ground stations, very powerful HP A700's will be installed, whereas the transportable station will contain a much more modest HP 9826A.

At both types of stations, the computer will perform the following functions. Prior to a satellite pass, it will calculate look angles and doppler shift from orbit-ephemeris information received from NORAD. During the pass, the computed look angles will be used for antenna steering. (The remote antennas will have fixed, broad beams at the transportable station, as will the VHF antenna at both the fixed and transportable stations.) The computed L-band doppler shift will be used as a tuning aid for receiver lockup. The computer also will control data acquisition through an interface, with data from approximately five passes being accumulated on one 2400-ft digital magnetic tape. Typically, one such tape will be recorded in a day of operation. (A more compact tape drive will be employed with the transportable receiver in flight, but not in ground operation. The 600-ft tapes to be employed in flight usually will contain data from a single satellite pass.)

The fixed stations all are remote from CONUS and from the data-analytical facilities of the participating organizations. It is for this reason that they will be

equipped with A700 computers, which will process both beacon and telemetered data into science-ready format. All raw tapes, however, will be retained. The transportable US station will be operated near an off-line computing facility most of the time, so it has not been equipped with full data-processing capability. Its operation at remote locations will be on relatively brief campaigns (several weeks), and airborne operation will be even more brief (several hours to a few days). Raw data from campaigns will be sent to the off-line computing facility frequently for processing.

Another difference between the fixed stations and the transportable US one is that the former will contain five UHF receiver channels, whereas the latter will contain only three. Airborne operation will preclude interferometer observations with remote antennas, the three UHF channels being used for single-antenna scintillation observations and TEC measurements. When in ground-based use, the three UHF channels in the transportable receiver will be used for either TEC or interferometer observations at different times, but not simultaneously. The Canadian transportable station will have some other differences, including less rapid sampling of scintillation data.

Preliminary documentation of the fixed and transportable US receivers has been prepared, respectively, by Livingston *et al*, (1983) and by Lansinger and Smith (1983). As itemized in Tables 2 through 5 of the former document, both types of stations will provide the following kinds of data. First, raw data will be recorded at 1600 bpi on nine-track binary tape in 0.5-sec records containing 2,050 sixteen-bit words. Each record will contain a header identifying the time, station location, satellite location, and antenna look angles. This will be followed by 128 data words including satellite attitude information and measurements from the magnetometer, J-package, AIM, and plasma monitor. Next will follow 1,750 words of beacon data in the form of 125 sets of I and Q pairs from the seven receiver channels (five channels plus two dummy pairs for the US transportable station). That is, scintillation data will be available as I and Q time series sampled 250 times per second (with Q of the L-band phase reference identically zero and I equivalent to amplitude). Table 2 gives link budgets and resulting data-quality measures for scintillation observations and telemetry recovery.

The data reduction performed in the field for the fixed stations and at PDNW near Seattle for the transportable US station will result in science-ready data from about a week's worth of passes being recorded on a so-called summary tape. The data compression stems solely from reduction of beacon data. Indeed, for all other experiments, the raw data will be repeated on the summary tapes in addition to recording of science-ready parameters. Furthermore, various kinds of geometry and observing-condition information will be contained on the summary tapes.

Table 2. RECEIVER LINK BUDGET FOR GROUND STATIONS

FREQ (MHz)	ELEV (DEG)	XTMTR PWR (dBm)	MISC SC LOSSES (dB)	XMT ANT GAIN (dB)	ERP (dBm)	SPACE LOSS (dB)	POLARIZATION LOSS (dB)	RCV ANT GAIN (dB)	RCVD PWR (dBm)	SYSTEM TEMP (°K)	BANDWIDTH, BIT RATE (Hz)	S/N, E_b/N_o (dB)	MIN DET S_4	MIN DET σ_ϕ (deg)	MIN DET TEC (10^{16} el/m^2)	MARGIN OVER $P_e=10^{-6}$ (dB)
	15			-1	+24	-142	-1	+1	-118			21	0.09	4	-	-
138	30	26	-1	0	+25	-138	-1	+4	-110	5000	200	29	0.04	2	-	-
	90			+1	+26	-134	0	+3	-105			34	0.02	1	-	-
	15			+1	+23	-152	-1		-120			28	0.04	2	0.06	-
390		23									2					
413	30	23	-1	+2	+24	-148	-1	+10	-125	560	200	33	0.02	1	0.03	-
436		23									2					
	90			-1	+21	-144	0		-113			35	0.01	<1	0.01	-
	15			+2	+34	-161	-1		-118			36, 23	0.02	-	-	10
1239	30	33	-1	+3	+35	-157	-1	+10	-113	145	200, 4098	41, 28	0.01	-	-	15
	90			-2	+30	-153	0		-113			41, 28	0.01			15

In addition to time, geodetic location of the station and satellite, the satellite attitude, and the azimuth, elevation, and range from the station to the satellite, the tape will contain the position and velocity of the satellite in geocentric coordinates and its location in offset-magnetic-dipole coordinates. It will also contain the strength and orientation of the magnetic field at the satellite, using the International Geomagnetic Reference Field (IGRF 80). Also included will be right ascension and declination of the sun.

As aids to comparison of *in-situ*, AIM, beacon, and external data, pertinent information also will be included about the magnetic field line through the satellite and the penetration points of the radio line of sight with the F layer (350 km) and the E Layer (100 km). The former will include the latitude, longitude, and altitude of the E-layer and F-layer footprints of the field line, and the latter will include the geographic and geomagnetic coordinates of the penetration points and the strength and orientation of the geomagnetic field there. Angles pertinent to scintillation analysis will be included, namely the zenith angle and magnetic heading of the propagation vector at the penetration points and its angles there relative to the magnetic field, the magnetic meridian, and the local L shell. Also for scintillation analysis, the reduced range needed for computing Fresnel-zone sizes will be included for the two penetration points.

Each P.I. has provided processing algorithms for use in reduction of data from his instrument. For instance, for the J-package, calibration factors have been provided that will permit conversion of instrument counts to electron number flux and energy flux in each of the energy channels of the three detector assemblies. Similarly, magnetometer output will be converted directly to magnetic-field components. Moreover, a latent VUV image will be present on tape when AIM is operated in imaging mode.

Quick-look parameters also will be available on the reduced-data tapes for the measurements made by the plasma monitor. Analysis of certain data from this instrument, notably curve-fitting analysis of the I-V relationships, must be done with considerable care, however. In general, the reduced data on the summary tapes should be useful for intercomparisons between instruments. Some experimenters, however, expect to perform detailed analysis from reprocessed raw data (also available on the summary tapes). All users of HiLat data are cautioned to discuss instrument and data-processing subtleties for specific experiments with the appropriate P.I.'s before forming conclusions based on summary data.

Because of the volume of beacon data to be recorded, it will not be possible to repeat raw data therefrom on the summary tapes. Moreover, beacon TEC and scintillation analysis is highly refined on the basis of Wideband experience. For overlapping 15-sec periods, the summary tapes will contain intensity (S_4) and phase (σ_ϕ, using a 20-sec detrend) scintillation indices for each beacon receiver channel (seven for the fixed stations, five plus two dummies for the transportable US station, L-band σ_ϕ identically zero for both). Perhaps of next most use by non-beacon experimenters will be phase and intensity spectra, each presented as 50 PSD samples equally spaced in log-frequency between 0.05 and 125 Hz. Also included will be the average amplitude-fade period and the intensity decorrelation time. Moreover, TEC will be presented from the UHF dispersive-phase record, with ambiguity resolved by means of $\Delta_2\phi$.

The most highly processed beacon data present on the summary tapes will be that from the interferometers. Those data will be presented as the axial ratio, orientation angle, and two-dimensional vector velocity of the diffraction-pattern correlation ellipse on the plane defined by the three UHF antennas, obtained from a best-fit procedure. Before using these data, researchers are cautioned to familiarize themselves with the analysis technique described by Rino and Livingston (1982) and to consult with Mr. Robert Livingston of SRI or one of the other beacon experimenters. Also present on the summary tapes, from the interferometers, will be rms phase-difference fluctuations between the three pairs of antennas, a much more straightforward parameter.

B. Dissemination of Data, Ephemeris Information, and Commands

The data tapes described in the foregoing subsection will be distributed via the network shown in Figure 3. The five upper blocks represent the five planned HiLat receivers and the organizations responsible for their operation and data collection. At the three fixed stations (Sondre Stromfjord, Tromso, and Churchill), raw data will be reduced to summary form on site. Raw data from the transportable US receiver (Rover) will be sent to PDNW for reduction, its home base being a field site near Seattle. The transportable Canadian receiver (King) is being fielded by a consortium of Canadian universities, organized by UWO, which will be responsible for data reduction and distribution.

The dashed lines in the figure represent the flow of raw tapes from the recording organizations to AFGL, which is acting as its own and DNA's archive point for HiLat. Copies of raw tapes (presumably of interest only for special, detailed analysis of beacon data) may be requested from the archive by any participating organization, but

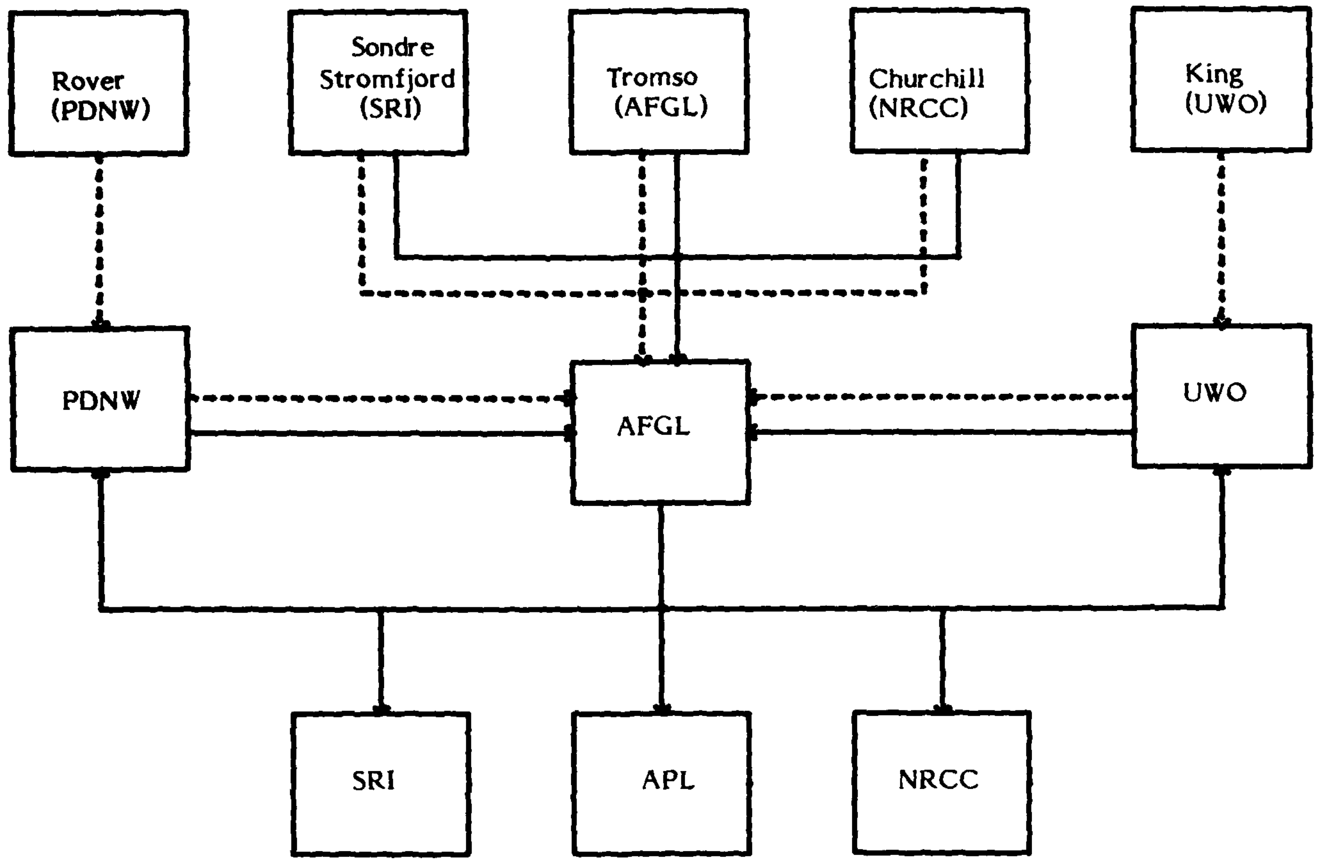

Figure 3. Data distribution network.

they will not be distributed routinely. The solid lines represent the flow of summary tapes through the AFGL archive, where they will be duplicated and distributed routinely to the participating organizations. A goal has been set for final distribution of summary data within one month from recording of the corresponding raw data.

For antenna steering and receiver tuning for ready acquisition of signal, the satellite trajectory for each pass will be computed at the receiving stations from ephemeris information provided by NORAD. Keplerian elements will be distributed by NORAD over the network shown in Figure 4. Distribution will be primarily by AUTODIN, coupled with some use of commercial Telex. For instance, NORAD will send the messages to the Canadian Department of National Defense (DND), which will retransmit them to Churchill and to the campaign locations of King. At the time of this writing, it is believed that transmission to Tromso will be directly from NORAD, but retransmission from AFGL may be necessary.

Although a full data station will not be operated by APL, it will receive ephemeris information for observing the satellite's technical health. The Naval Astronautics Group (NAG) will employ the ephemeris for transmitting operating commands to HiLat in a manner similar to its operational loading of commands into the TRANSIT Navy Navigation Satellites.

Operating personnel from SRI and PDNW, respectively, will hand-carry ephemeris messages from local US military facilities to the Sondre Stromfjord station and to Rover when the latter is operating near Seattle. Other arrangements will be made by PDNW (e.g., commercial Telex) when Rover is operating on a remote campaign. When it is operating aboard AFGL's Airborne Geophysical Observatory, standard military communications channels will be employed.

Unlike P76-5, which was able to operate its single payload (the Wideband beacon) continuously, P83-1 has five payloads to support, and its power must be managed conservatively. For this purpose, it has a timer on board, which will permit payload operation only during one quarter of each orbit. The orbital phase of the operating period, which usually will be over the earth's northern-most quadrant, can be shifted by command from the ground. The timer phase and instrument modes will be set in advance by means of commands injected by NAG during passes of P83-1 over its network of stations, headquartered at Pt. Magu, CA. Mode requests from P.I.'s, mainly of AIM and the J-package, normally will be assembled by the Project Scientist at PDNW and passed to NAG for injection to the satellite. Command requests for technical management of the satellite normally would come from the Project Engineer at APL. Only PDNW, APL, and DNA are authorized to issue command requests.

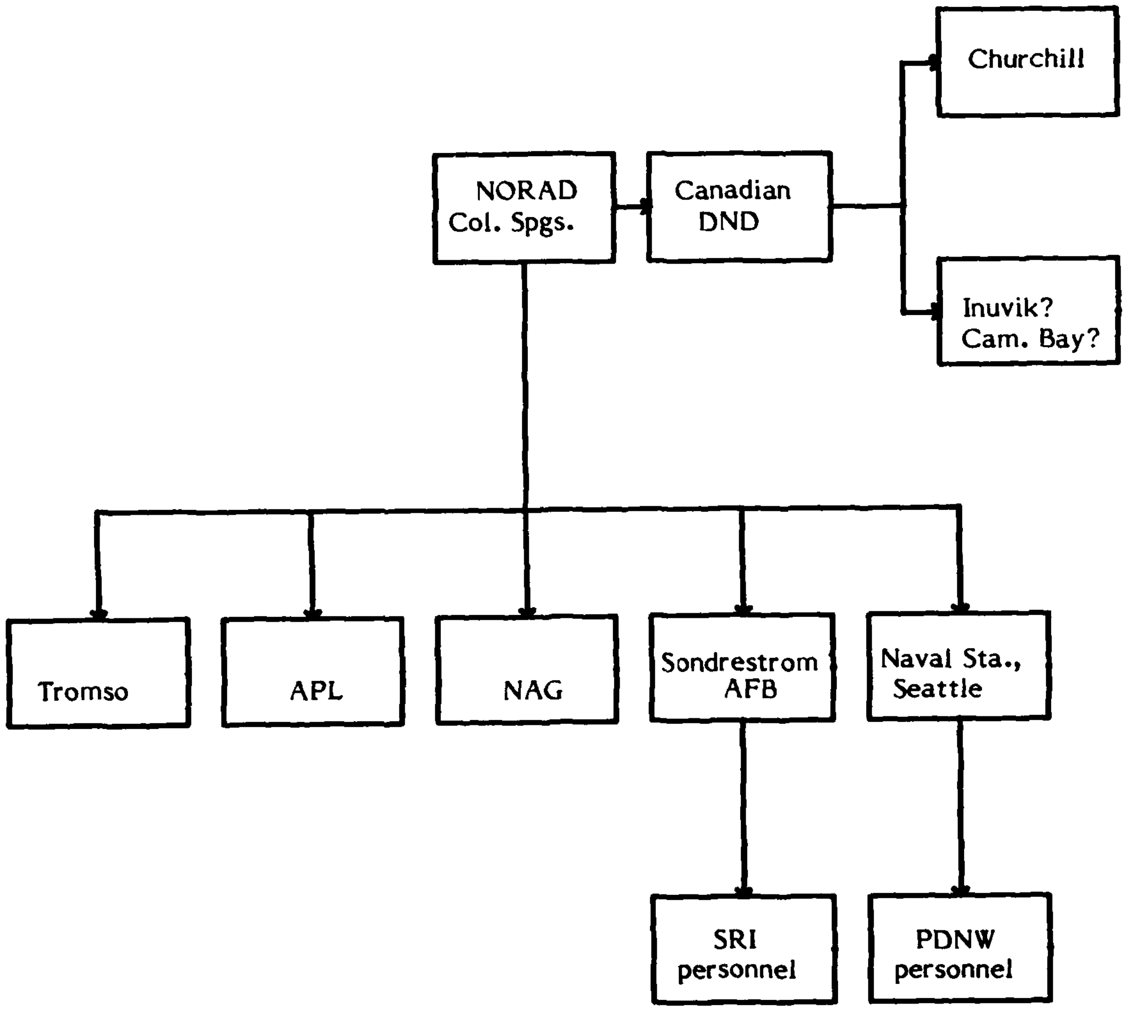

Figure 4. Ephemeris distribution network.

VI. CONCLUSIONS

As launch of P83-1 approaches, the HiLat Science Team looks forward, after a period of spacecraft stabilization and receiving-station shakedown, to a fruitful period of data collection and analysis. At its Readiness Review, which took place at APL on 31 May 1983, the satellite was found ready for scheduled shipment to VAFB on 4 June. Final instrument checks will be made in the field on 21 June, and launch is scheduled for 27 June at 1530 Z. Important checkpoints following launch will be verification of spacecraft telemetry on the first pass over VAFB and several checks at APL on the 6th orbit. The Satellite is expected to be ready for routine scientific operation within three weeks after launch.

The Sondre Stromfjord receiver will be operated at SRI for about two weeks after launch and will be shipped to Greenland at the end of July. Data should begin to flow from the field to SRI during the second week of August. Initially, data will be distributed from there, pending complete checkout of the spacecraft and the receiver. The data distribution network laid out in Figure 3 will be put into operation on 1 October, picking up data from the other stations as they come on line.

The Tromso station will start operating by early September, and Rover will begin operating near Seattle in October. It is scheduled for its first campaign, to Barrow AK, in January and February of 1984. The Churchill station is to begin operation in November 1983, and King will be operated two to three weeks at a time, four to five times per year, at various locations in Canada, starting in the Spring of 1984.

As the data stations come on line, the Science Team will begin analyses of three generic types: (1) statistical data-base development, (2) process-oriented analysis, and (3) event-oriented analysis. The first will involve primarily index-type parameters for establishing occurrence trends, phenomenological correlations, etc. The most direct application of these results will be to systems operating in the ambient environment, via essentially empirical scintillation models, but there will be some application also to hypothesis testing.

By process-oriented analysis is meant a focused continuation of the investigations carried out individually on specific ionospheric processes by members of the Science Team. The individual experience and interests of team members will be exploited, but they will not be allowed to dominate HiLat activities. There is strong consensus on the team about the need for individual members to maintain a broad perspective in their analyses.

One means for promoting broad perspectives will be event-oriented analysis, in which the objective will be to understand the interactions between the various relevant individual processes. This probably will be the most direct approach to testing of various hypotheses about the evolution of scintillation-producing plasma structure. A necessary condition for success of event-oriented analysis will be judicious selection of events. Among the "events" chosen will be one or more times of geophysical quiet, so that convective development of plasma structure may be understood in the "simple" case of a uniform driver (presumably, a fairly constant $\vec{E}$ field). Thereafter, more complicated discrete geophysical events will be studied.

Success of HiLat, no doubt, will be enhanced by contributions from other data sources. For example, AFGL plans extensive optical instrumentation of the polar cap during the HiLat era, to obtain synoptic information on the motions of plasma features and to provide ancillary data on velocity of the neutral gas in the high-latitude thermosphere. Synoptic information on convecting small-scale ionospheric structure also is expected from an HF radar to be operated at Goose Bay, Labrador, by collaborating scientists at APL and from a Canadian backscatter radar to illuminate the region near Churchill as part of the CANOPUS program. Moreover, a great deal of very relevant background information is anticipated from the incoherent-scatter radars at Sondre Stromfjord and Tromso.

Finally, interpretation, synthesis, and application of HiLat results will be facilitated greatly by the participation of plasma theorists and numericists from NRL and by systems specialists and other researchers from MRC and Berkeley Research Associates. The resources being made available to the HiLat Science Team offer its members an exciting prospect for understanding the development of scintillation-producing plasma structures at high latitudes and elsewhere and for the meeting of HiLat program goals.

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